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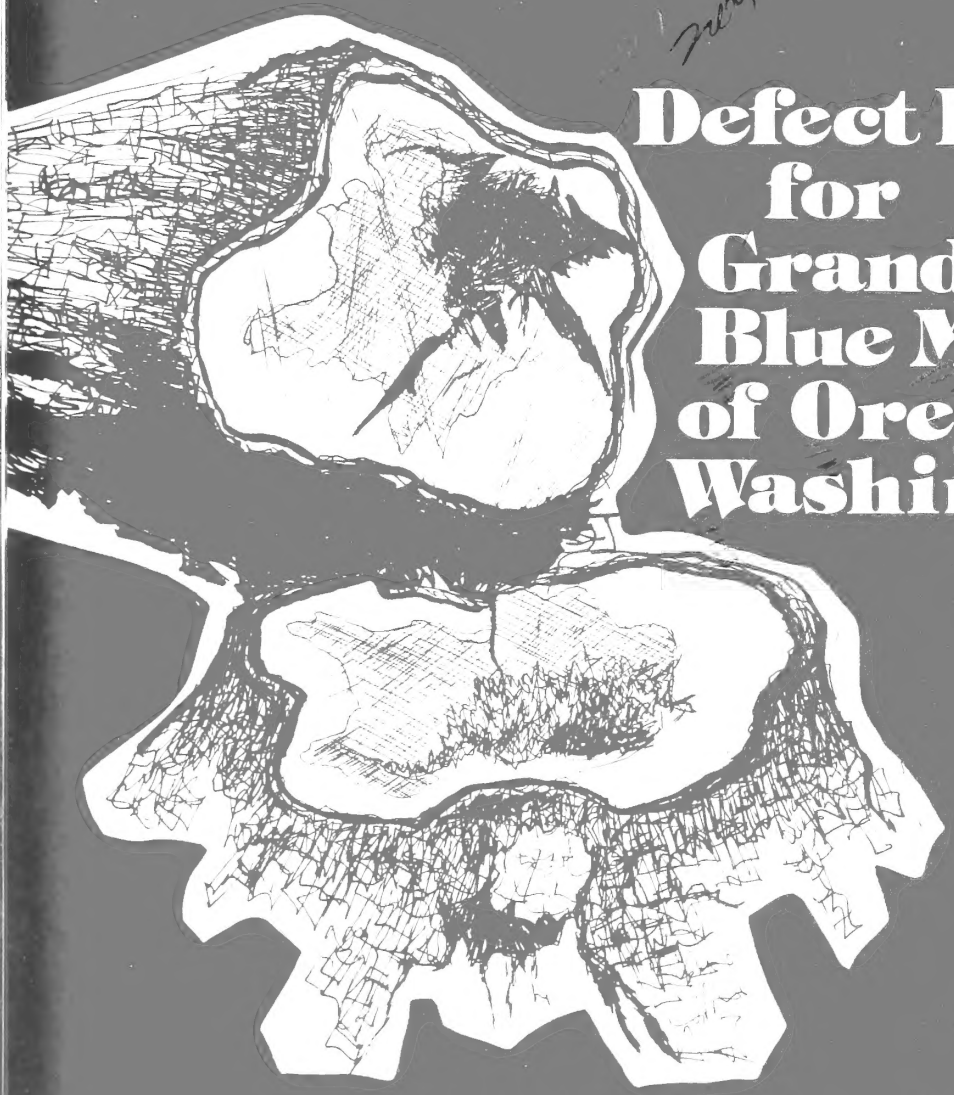

Defect Estimation for Grand Fir in the Blue Mountains of Oregon and Washington

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ABSTRACT

A total of 1,090 grand firs with and without various indicators of defect were dissected and studied on 65 plots from 11 widely scattered localities in the Blue Mountains. Two methods for making defect deductions for grand firs are given. (1) Defect percentages of gross merchantable Scribner board-foot and cubic-foot volumes are tabulated by d.b.h. and age. Then constant defect percentages must be added for various indicators. Multiple regression equations, used to derive the indicator defect percentage tables, are also provided. Equations excluding age as a variable are included for use when age is unknown. (2) Average length deductions below and above various indicators plus flat factors for hidden defect are also presented.

KEYWORDS: Grand fir, defect deduction (merchantable volume).

CONTENTS

INTRODUCTION

Grand fir is an important component of the mixed-conifer forests at middle to higher elevations in the Blue Mountains. In recent years the economic value and utilization of this species have greatly increased. Management of grand fir is difficult because of excessive defect, mainly decay. In particular, timber cruisers are handicapped because accurate methods for making defect estimates in standing trees are not available. To remedy this situation, a defect study was made in the Blue Mountains from 1959-63.

Two methods have previously been developed for estimating the extent of defect in Douglas-fir, western larch, Engelmann spruce, and grand fir: (1) equations developed through multiple regression analysis whereby a percentage of total tree cubic- or board-foot volume is deducted dependent upon tree age and d.b.h. and presence or absence of various indicators of internal defect,[1/] (2) average length deductions below and above indicators and a flat factor for defect associated with no or minor indicators.[2/]

Since these two methods were developed, cull rules for true firs have changed, requiring a revision in present board-foot, defect-indicator percentages. The previous cull rule indicated that a true fir log was considered cull if it was more than 50-percent defective. Because utilization practices have improved and the economic value of true fir logs has increased, logs with greater defect are now used. A true fir log is now considered cull if it is more than two-thirds defective. Because of this change, the board-foot, indicator-defect percentages previously reported are too high.

In addition, the second method--average length deductions below and above various indicators--has been only presented in a slide-tape program and never published.

The objectives of this paper are to report revised grand fir defect indicator percentages and to make the indicator length deduction factors more readily available.

1/ Paul E. Aho. Defect estimation for grand fir, Engelmann spruce, Douglas-fir, and western larch in the Blue Mountains of Oregon and Washington. USDA Forest Service Pacific Northwest Forest and Range Experiment Station, 26 p., illus., 1966. Portland, Oregon.

2/ Paul E. Aho, Donald P. Graham, and John H. Thompson. Defect estimation in the associated species of the Blue Mountains--A guide for the cruiser. USDA Forest Service, Region 6, slide-tape movie, 1967. Portland, Oregon.

/ *abies grandis, injuries, marketable value]

STUDY METHODS

Study trees were taken on one-fifth-acre plots systematically selected in mature and overmature stands. All trees 5-inch d.b.h. and larger were dissected into 16-foot logs to a top d.i.b. of 4 inches for cubic-foot volume measurement. Board-foot volumes of trees 11-inch d.b.h. and larger were measured to a top d.i.b. of 8 inches. Logs were further dissected at possible external indicators of decay and wherever necessary for measurement of decay columns. Age at stump height, d.b.h., and location and description of decay indicators, if present, were noted for each tree.

Cubic-foot volumes of logs and decay columns were computed by Smalian's formula. No arbitrary culling rules were used in cubic-volume measurements.

Board-foot volumes of logs in trees of 11-inch d.b.h. and larger were computed by the Scribner log rule, and board-foot deductions for decay, shake, and frost cracks were made by the squared-defect method. In board-foot measurements logs more than two-thirds defective were considered cull.

Multiple regression analysis was used to develop equations for estimating defect percentages for individual trees. Individual trees were treated as independent observations even though they were selected as a group on the one-fifth-acre plots. Despite statistical disadvantages, plots were used instead of random tree selection, because they made it possible to obtain many more trees with less time and effort.

DEFINITIONS

Defect for cubic-volume measure includes decay only; decay, shake, check, and frost cracks are included in board-foot measure. Crook, sweep, breakage in felling and missing parts of trees, such as scars caused by fires and broken tops, are not deducted in either volume measurement.

Defect percentages include the appropriate defect within the tree from a 1-foot stump height to a 4-inch top (d.i.b.) for cubic-foot volume for trees 5-inch d.b.h. and larger and to an 8-inch top (d.i.b.) for Scribner board-foot volume for trees 11-inch d.b.h. and larger.

Defect indicators are visible external indications that there may be some type of defect within the merchantable part of the tree. Some indicators are more consistently associated with defect than others. Statistical analysis indicated that conks of the Indian paint fungus (*Echinodontium tinctorium*), basal injuries, trunk injuries, frost cracks, and dead and broken tops are consistently associated with defect in grand firs and thus have value in defect estimation. Minor indicators--crooks, forks, dead vertical branches, basal and trunk injuries less than 6 years old, and trunk injuries less than 1 foot long--are not frequently associated with defect or may be associated with only small amounts. Their value in defect prediction is unimportant.

Conks are the external fruiting bodies of fungi causing decay within trees. The only fungus found consistently producing conks on grand firs was the Indian paint fungus (fig. 1). Significant amounts of decay by this fungus were seldom found without associated conks. They are the most reliable defect indicators for grand fir, and trees bearing Indian paint fungus conks are frequently rotten from the ground line to above the 4-inch-top diameter (fig. 2).

INDICATES DECAY →

Figure 1.--Indian paint *fungus conks*.

They are generally seen protruding at the base of branch stubs but may also be attached to live branches. When located in the live crown, they can be easily overlooked or mistaken for burls, which do not indicate the presence of decay.

Other fungi such as *Pholiota adiposa* and *Hericium abietis* may produce sporophores on or near injuries at certain times of the year. In these cases deductions should be based on the type of injury present.

Figure 2.--Cross sections at 1, 2, 7, 21, 29, 37, and 41 feet showing the extent of Indian paint fungus decay. Note the conks attached to the cross sections at 7 and 21 feet.

← *INDICATES DECAY*

Figure 3.--Basal injury with visible decay.

Figure 4.--Old, nearly grown-over basal injury. Inconspicuous injuries such as this one should not be overlooked because significant errors in volume estimates may result. →

Basal injuries include open or closed wounds--caused by fire (fig. 3), root rots, falling trees, or mechanical logging equipment--in contact with the ground (basal frost cracks should not be included here). They are the second most reliable defect indicator in grand fir. Some basal scars are inconspicuous (fig. 4) and sometimes overlooked; thus significant errors in volume estimates may result. Basal injuries less than 6 years old should be ignored since little or no defect is associated with them.

Trunk injuries include open or closed wounds--caused by falling trees, lightning, animals, and logging equipment (fig. 5)--below the merchantable top but not in contact with the ground. Wounds less than 6 years old and less than 1 foot long should be ignored (fig. 6).

INDICATES DECAY →

Figure 5.--Old, partially healed trunk injury.

DOES NOT INDICATE DECAY →

Figure 6.--Trunk injury less than 1 foot long.

Figure 7.--Bleeding frost crack.

Frost cracks are open or closed scars or seams probably caused by freezing (fig. 7). Frost cracks are very common in grand fir and are associated with wetwood (fig. 8). The term "wetwood" is used to describe the occurrence of excessive wood moisture at or near the center and usually in the butt log near the ground in many grand fir trees. It is also commonly associated with injuries higher in the tree. The specific cause of wetwood is unknown. Trees with bleeding frost cracks at their bases will often have Indian paint fungus conks higher on their trunks. Decay associated with the conks will not usually extend into the wetwood and frost crack area, probably because the wood is too wet or because of antagonism by micro-organisms present in the wetwood zone. Although decay may not develop in the wetwood zone, there is generally considerable defect due to shake, checks, and frost cracks.

Figure 8.--Cross section through frost crack showing associated wetwood and shake.

← *INDICATES DECAY*

Figure 9.--Broken top.

INDICATES DECAY →

Figure 10.--Dead top.

Top injuries are broken (fig. 9) or dead tops (fig. 10) occurring below the merchantable top diameter. Recently broken or killed tops should be ignored.

Minor indicators include forks (fig. 11), crooks (fig. 12), dead vertical branches (fig. 13), basal (fig. 14) and trunk (fig. 15) injuries less than 6 years old, and trunk injuries less than 1 foot long (fig. 6). Certain types of these indicators may only infrequently be associated with decay, or the associated decay may be quite limited. Statistical analysis of the relation between these indicators and associated decay indicated little or no effect on defect estimation. It is not necessary for the cruiser to make defect deductions for these minor indicators.

DOES NOT INDICATE DECAY →

Figure 11.--Fork.

Figure 12.--Crook.

Figure 13.--Dead vertical branch.

DOES NOT INDICATE DECAY

Figure 14.--Basal injury less than 6 years old.

Figure 15.--Trunk injury less than 6 years old.

DEFECT ESTIMATION IN INDIVIDUAL GRAND FIRS

Indicator defect factors are presented as (1) percentages of gross merchantable tree cubic-foot and Scribner board-foot volumes, and (2) average length deductions below and above indicators with flat percentage factors for hidden defect. The defect factors are based on a sample of 1,090 trees, with and without various indicators, from 65 one-fifth-acre plots in 11 widely scattered localities. Both methods of estimating defect may often be fairly accurate with small samples, perhaps even with single trees; however, greatest accuracy will be obtained when they are applied to large numbers of trees. The two methods cannot be used together. In a given timber cruise, one or the other estimation method must be used.

Indicator Percentage Defect Factors

Defect percentages derived from multiple regression equations (see appendix) are tabulated by d.b.h. and age. Constant defect percentages must be added to those obtained from the tables when various indicators are present. Equations for use when ages are not available are also included in the appendix. If the equations are to be used in a computer program, consideration must be given to the fact that defect percentages for some combinations of d.b.h., age, and indicators can be less than zero or greater than 100 percent. In these cases, provision should be made in the program to set the percentages at zero or 100 percent.

Application of percentage defect factors.-- Accurate application of defect percentages in tables 1 and 2 requires familiarity with the indicators that are reliably associated with defect. Sample trees must be carefully examined, the presence of meaningful indicators noted, and d.b.h. and age measured.

Defect percentages can be determined from the appropriate table or by computer using the equations in the appendix.

For instance, a 16-inch, 160-year-old grand fir without indicators would have deductions of 2 percent of its gross merchantable cubic volume (table 1) and 7 percent of its Scribner volume (table 2). If the same tree has one or more Indian paint fungus conks and a basal injury 6 or more years old it would be necessary to add 28 percent for the conks and 6 percent for the basal injury to the 2-percent deduction previously obtained from table 1, to get a total cubic-foot deduction of 36 percent. The additional deductions for these indicators in board foot measure are 56 percent for the conks and 21 percent for the basal injury for a total deduction of 84 percent (table 2).

Indicator Length Deductions and Flat Factors for Hidden Defect

Many timber cruisers determine net tree volumes by deducting portions of trees below and above visible indicators of defect. Therefore, average length deductions are presented for the major indicators occurring on grand fir (table 3). Length deductions include all defect above and below indicators, except when defect can only extend in one direction, such as above basal injuries or below broken tops.

The length deductions are averages derived from dissection and measurement of relatively large numbers of trees; however, there was considerable variation in decay column length for a given type of indicator. Questionable results may occur if the defect factors are applied to small numbers of trees.

From table 3, it is obvious that except for Indian paint fungus conks, there is a large percentage of each indicator that

Table 1.--*Defect in percent of gross merchantable cubic-foot volume for grand fir trees by age and d.b.h.*[1/]

Add these constants for each type of defect indicator present: Indian paint fungus conks 28 percent, basal injuries 6 percent, trunk injuries 8 percent, frost cracks 2 percent, and top injuries 7 percent

Tree d.b.h. (inches)	Tree age (years)																	
	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400
	Percent																	
5	0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
6	0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
7	0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	13	14	15
8	0	0	1	2	2	3	4	5	6	7	8	9	10	11	12	13	14	15
9	0	0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
10	0	0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
11	0	0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
12	0	0	0	1	2	3	4	5	6	7	7	8	9	10	11	12	13	14
13	0	0	0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
14	0	0	0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
15	0	0	0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
16	0	0	0	0	1	2	3	4	5	6	7	8	9	10	11	11	12	13
17	0	0	0	0	0	1	2	3	4	5	6	7	8	9	10	11	12	13
18	0	0	0	0	0	1	2	3	4	5	6	7	8	9	10	11	12	13
19	0	0	0	0	0	1	2	3	4	5	6	7	8	9	10	11	12	13
20	0	0	0	0	0	1	2	3	4	5	6	7	8	9	10	11	12	13
21	0	0	0	0	0	1	2	3	4	4	5	6	7	8	9	10	11	12
22	0	0	0	0	0	0	1	2	3	4	5	6	7	8	9	10	11	12
23	0	0	0	0	0	0	1	2	3	4	5	6	7	8	9	10	11	12
24	0	0	0	0	0	0	1	2	3	4	5	6	7	8	9	10	11	12
25	0	0	0	0	0	0	1	2	3	4	5	6	7	8	9	9	10	11
26	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8	9	10	11
27	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8	9	10	11
28	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8	9	10	11
29	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8	9	10	11
30	0	0	0	0	0	0	0	1	2	2	3	4	5	6	7	8	9	10
31	0	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8	9	10
32	0	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8	9	10
33	0	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8	9	10
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35	0	0	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8	9
36	0	0	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8	9
37	0	0	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8	9
38	0	0	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8	9
39	0	0	0	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8
40	0	0	0	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8

[1/] Derived from equation 1 in the appendix.

Table 2.--*Defect in percent of gross merchantable Scribner board-foot volume for grand fir trees by age and d.b.h.*[1/] *Add these constants for each type of defect indicator present: Indian paint fungus conks 56 percent, basal injuries 21 percent, trunk injuries 19 percent, frost cracks 7 percent, and top injuries 12 percent*

Tree d.b.h. (inches)	Tree age (years)																	
	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400
	Percent																	
11	0	1	4	7	9	12	15	18	21	23	26	29	32	34	37	40	43	45
12	0	0	3	6	9	11	14	17	20	22	25	28	31	33	36	39	42	44
13	0	0	2	5	8	10	13	16	19	21	24	27	30	32	35	38	41	43
14	0	0	1	4	7	9	12	15	18	20	23	26	29	31	34	37	40	43
15	0	0	0	3	6	8	11	14	17	19	22	25	28	31	33	36	39	42
16	0	0	0	2	5	7	10	13	16	19	21	24	27	30	32	35	38	41
17	0	0	0	1	4	7	9	12	15	18	20	23	26	29	31	34	37	40
18	0	0	0	0	3	6	8	11	14	17	19	22	25	28	30	33	36	39
19	0	0	0	0	2	5	7	10	13	16	18	21	24	27	29	32	35	38
20	0	0	0	0	1	4	6	9	12	15	17	20	23	26	28	31	34	37
21	0	0	0	0	0	3	5	8	11	14	16	19	22	25	28	30	33	36
22	0	0	0	0	0	2	5	7	10	13	16	18	21	24	27	29	32	35
23	0	0	0	0	0	1	4	6	9	12	15	17	20	23	26	28	31	34
24	0	0	0	0	0	0	3	5	8	11	14	16	19	22	25	27	30	33
25	0	0	0	0	0	0	2	4	7	10	13	15	18	21	24	26	29	32
26	0	0	0	0	0	0	1	3	6	9	12	14	17	20	23	26	28	31
27	0	0	0	0	0	0	0	2	5	8	11	14	16	19	22	25	27	30
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38	0	0	0	0	0	0	0	0	0	0	0	3	6	9	11	14	17	20
39	0	0	0	0	0	0	0	0	0	0	0	2	5	8	10	13	16	19
40	0	0	0	0	0	0	0	0	0	0	0	1	4	7	9	12	15	18

[1/] Derived from equation 3 in the appendix.

Table 3.--*Length deductions for most reliable indicators on grand fir*

Indicator	Percent of indicator associated with decay	Average length deduction	
		Below indicator	Above indicator
		Feet	
Indian paint fungus conks	100	17	20
Basal injuries	79	--	8
Trunk injuries	62	2	4
Frost cracks	32	--	3
Broken or dead tops	50	3	--

is not associated with decay and thus would require no deductions. However, in most cases there is no way of telling which of these indicators can be ignored by looking at the standing tree. Therefore, the average deduction for a given indicator should be applied to each individual tree with that indicator.

Application of length deductions and flat factors for hidden defect.-- The length deductions in table 3 are for the most reliable indicators of defect in grand fir. Application of the average length deductions is as follows: If a tree has a series of Indian paint fungus conks and a broken top, deduct those portions of the tree from 17 feet below the lowest conk to 20 feet above the highest conk and from the broken top to 3 feet below (table 3). In cases where there are two or more indicators in one segment of the tree, use the indicator that results in the largest deduction. For instance, if there is a trunk injury with a series of Indian paint fungus conks, ignore the trunk injury and base the deduction on the conks.

Total net volume of sample trees, determined by using the indicator length deduction factors, must be further adjusted for hidden defect. Hidden defect includes shake and decay, which is caused by fungi entering trees through roots, branches, or injuries that are not visible because they are grown over or are too high in the live crown. Included with hidden defect are the small amounts of decay that are occasionally associated with minor indicators, such as crooks, forks, dead vertical branches, basal and trunk injuries less than 6 years old, and trunk wounds less than 1 foot long.

Total net cubic-foot and Scribner board-foot volumes must be reduced by 1 and 3 percent, respectively, to account for hidden defect. This gives the net sound volume of the sample, excepting deductions for sweep, breakage in logging, and missing parts of trees--such as broken tops or portions of butt logs burned away by fire.

APPENDIX. DEFECT ESTIMATING EQUATIONS

The following multiple regression equations are for estimating percent cubic-foot and Scribner board-foot volume loss for individual grand firs in the Blue Mountains of Oregon and Washington. The first and third equations were used to derive tables of defect percentages for tree d.b.h., age, and various defect indicators (tables 1 and 2). Since it is not always possible or feasible to obtain tree ages while cruising, equations without age as a variable are also included (equations 2 and 4).

There are limitations in the use of these equations in computer programs. Some combinations of tree d.b.h., age, and defect indicators may give defect percentage estimates less than zero or greater than 100. Provision should be made in the program for setting these erroneous percentages to zero or 100 percent.

Cubic-foot Volume Equations

1. $P_c = -2.583 + 0.049A + 6.416B + 27.780C - 0.223D + 8.374E + 2.223F + 6.903G$

$(R_2 = 0.58)$

2. $P_c = 2.709 + 8.016B + 28.596C - 0.089D + 9.024E + 3.772F + 7.056G$

$(R_2 = 0.56)$

Scribner Board-foot Volume Equations

3. $P_b = 0.692 + 0.138A + 21.154B + 55.782C - 0.956D + 19.242E + 6.598F + 12.419G$

$(R_2 = 0.62)$

4. $P_b = 17.159 + 25.737B + 58.057C - 0.634D + 21.329E + 10.253F + 12.032G$

$(R_2 = 0.58)$

Where:

P_c = percent of gross merchantable cubic-foot volume that is cull.

P_b = percent of gross merchantable board-foot volume that is cull.

A = tree age.

B = 1 if one or more basal injuries at least 6 years old are present; 0 if no basal injury is present or if one or more basal injuries less than 6 years old are present.

C = 1 if one or more Indian paint fungus conks are present; 0 if no conks are present.

D = tree diameter outside bark at breast height.

E = 1 if one or more trunk injuries at least 6 years old and more than 1 foot are present; 0 if no trunk injuries are present or if one or more trunk injuries less than 6 years old and less than 1 foot are present.

F = 1 if one or more frost cracks are present; 0 if no frost cracks are present.

G = 1 if a dead or broken top is present; 0 if no dead or broken top is present.

R^2 = the coefficient of determination (the amount of variation in percent decay or cull that is explained by the variables in a multiple regression equation).

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KEYWORDS: Grand fir, defect deduction (merchantable volume).

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The FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.